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Intercondylar Notch Width and Inner Angle of Lateral Femoral Condyle as the Risk Factors for Anterior Cruciate Ligament Injury in Female Handball Players in Herzegovina

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A B S T R A C T

The principal purpose of this prospective study was to examine intercondylar notch size and the value of inner angle of lateral femoral condyle as the risk factors for noncontact anterior cruciate ligament ACL injury and than to correlate them to the physical values of the athletes such as body mass index (BMI), hight, wight, etc There are indentified two type of risk factors, external include shoes-surface interaction, type of playing surface, weather conditions and internal include anatomic, neuromuscular, biomechanical and hormonal factors that may predispose female athlets to noncontact injury of ACL. Among anatomic factors, intercondylar notch stenosis and larger inner angle of lateral condyle of femur as the factors which can cause impigement of ACL, were related to an increased risk of injury of ACL. In this study were included 51female athlete. In the study group there were 24 female handball players with ACL tear and in control group there were 27 female handball players without any type of injury of the knee, who are practicing handball on a daily basis for at least for two years. In the first step, were gathered clinical data performed by orthopaedic surgeon. In the second step, the femoral notch width and the inner angle of lateral condyle of femur were measured on coronal MR-images. Study has shown that value of inner angle of lateral condyle of femur was significantly higher in athletes with ACL tear compared to those without. Value of width of intercondylar notch was statisticaly smaller in athletes with ACL tear, comprared to those without. In the conclusion the inner angle of lateral femoral condyle is better predicting factor for ACL tear in young female handball players compared to intercondylar notch width.

Key words: *intercondylar notch width, lateral condyle, anterior cruciate ligament, female handball, Herzegovina*

Introduction

Higher incidence of participation of young female in sports, specialy in elite team sports, such as handball, soccer, basketball and volleyball, is related to higher incidence of injuries of musculoskeltal system. The most frequent are articulation injuries, and among these, knee injury is conceivable at first place. It is estimated, that they present 15–50% of all injuries among sportsmen[1]. Some studies found that about 40% of all knee injuries present as isolated tears of ACL and 78% of athletes had their injury in noncontact situations[2].

It has been reported that women are 2–8 times more likely to sustain an ACL injury compared to their male counterparts who participate in the same sports[3–5]. Specifically, women tend to land from a jump with straighter legs, have greater knee valgus, activate the quadriceps prior to the hamstrings, these aspects have been identified as key mechanisms in the etiology for non-contact ACL injuries[6]. The ACL tear is very serious injury that is related to high financial costs of treatment and rehabilitation that takes at least 4–6 months, resulting in loss of playnig time.

There are several most frequent mechanisms associated with high risk of noncontact tear of ACL and these are changing direction or stopping, pivoting with the

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knee in fully extension and foot firmly attached to the ground[7–9]. Another described mechanisms include having knee in full extension or flexion, larger varus and valgus of the knee with invard rotation, when landing from jump.

There are indentified two type of risk factors, external include shoes-surface interaction, type of playing surface, weather conditions and internal include anatomic, neuromuscular, biomechanical and hormonal factors that may predispose female athletes to noncontact injury of ACL. Among numerous anatomic factors, intercondylar notch geometry was one of the most studied subjects in the last 20 years. Various studies have been analyzing shape, width, height, volume of intercondylar notch, notch width index (NWI), position of ACL on different sections of intercondylar notch, relation between ACL and medial edge of lateral femoral condyle and than these indices were correlated to physical characteristics of the athletes such as weight, height, body mass indeks-BMI). It has been suggested that impigement of ACL to the medial edge of anterior part of lateral femoral condyle could be one of the most important predisposing risk factors for ACL tear. Van Eck et al. analyzing importance of shape of intercondylar notch, but there was no relationship between notch shape and BMI or weight. At female, regardless of its shape, intercondylar notch is wider at its basis and central part[10]. Palmer[11] in 1938, has established, that narrowed intercondylar notch can be risk factor for ACL tear.

Trough the time, various authors have measured distal part of the femur in a different ways. Some have taken measurements on cadaveric knees, another evaluated on plain radiographs, but today major part are using computed tomography and MR imaging. Souryal et al. have reported that athletes, who sustained bilateral tears of ACL, have narrower intercondylar notches in relationship to control group[12,13]. Another three studies have measured width and volume of intercondylar notch and have researched relationship between the risk of ACL tear and stenosis of intercondylar notch[14–16]. Baker et al.[17] have found, on antropomorphic study of 280 femurs, that mean height of intercondylar notch is lower at female in relationship to male, and that there is no difference between controlateral side at same person. In the prospective study, La Prade et al.[18] have concluded that there was statistically significant relationship between stenosis of intercondylar notch and ACL tear and they have suggested importance to perform notchplasty as part of ACL reconstruction in athletes with intercondylar notch stenosis. Lund-Hansen et al.[16] have shown, comparing intercondylar notch width of female handball players, that the players with 17 mm or less anterior notch width were 6 times more susceptible to anterior cruciate ligament injury compared to players with wider notch width. Shelbourne et al.[19] have suggested intercondylar notch width as the risk factor for ACL tear, and also they have tried to correlate it to the hight of the athletes. On the contrary Herzog et al.[20] found no statistically significant difference in mean notch width index in sporstsmen with or without chronic ACL tear. Stijak et al.[21] have examined position of ACL in intercondylar notch as one of the risk factors that lead to ACL tear. They have measured on plain radiographs and MR-images angle of ACL in sagittal and coronal section and angle of inner edge of lateral femoral condyle on coronal and axial section. They have conducted study on male and female population with ACL injury and correlate them to another group of patient with diagnosis of patellofemoral pain. Only few studies have examined angle between ACL attachment and lateral femoral condyle. There was suggested that during knee movement there is stronger strain on femoral attachment of ACL graft comparing: to tibial ACL graft attachment[22]. The higher incidence of ACL tears at femoral attachment is in relationship to placement and appearance of ACL and angle of femoral attachment and medial part of lateral femoral condyle and can cause ACL impigement.

The hypothesis of the study is: ACL injuries are often due to a larger internal angle of the lateral femoral condyle the horizontal plane than the width of intekondylar notch.

The aim of this study is to examine the intercondylar notch width and the inner corner of the lateral femoral condyle as risk factors for ACL injury. Next goal is to examine the relationship between these risk factors for ACL injury with physical characteristics of athletes i.e. weight, height and BMI.

Materials and Methods

We decided to trial conduct in women's handball population Herzegovina. All participants were informed about our study and voluntarily agreed to participate in the study. We also got the approval of the Ethics Committee SKB Mostar to conduct the study. We examined 24 handball female players who had a unilateral ACL injury Influenced. The control group was 27 healthy handball female player, who had not complained of any problems with his knee. All's handball deal with on a daily basis for at least two years. Each of the handball players was made a clinical examination by orthopedist, where apart from weight, height, BMI calculation has been done and the measurement of Q angle, and questioned the orthopedic tests to test the phenomenon of »drawers«, Lachman test, asked about place in the handball team and how did they injured the knee. After orthopedic examination was made in MR knee examination by a standard protocol. Injured is injured knee examined, except those which made reconstruction of the ACL and they were reviewed a healthy knee. In healthy control group examined the knee of free choice, it is usually to either knee reflectors feet. All participants in the study, we set the position of supination, with the knee in extension and slight external rotation (10°–15°) in 1.0T magnet (Siemens, Harmony, Erlangen, Germany) using the knee coil (dedicated circumferential extremity coil). The subjects were further immobilized with sand bags in the center of a coil. All respondents were done our complete knee MR exami-

nation. All the layers were 4 mm in thickness, and spacing between the layers was 0.2 mm with a field of view of 16 cm, matrix 512×256, and the two measurements. But most importantly we were hair sagittal PD FS TSE sequence (3340/15-TR/TE), where we confirmed the injury to the ACL injured and axial FS TSE T2 sequences (4000/46-TR/TE) where we have done in all subjects the above-mentioned measurements of the width interkondilarne recesses and internal values of the angle of the lateral condyle femoralnog in the horizontal plane. The angle of the inner side of the lateral femoral condyle in axial plane (Figure 1) is determined by two lines. One line (a) passes through the lowest point femoral condyle, and the second line (b) passing (monitor) the medial aspect of the lateral femora condyle. Precision measurement of angles was around 0.5°.

Intercondylar notch width (Figure 2), we measured the axial MRI view of the secondary part popliteal groove that follows the lateral aspect of the lateral femoral condyle. We drew a line (a) through the outermost points of both condyles. We drew a vertical line (b) at right angles to the horizontal line at the level of the deepest point of the roof intercondylar notch of the femur and in the middle of that line drew a line parallel with the horizontal line that connects the condyles. At this level, we measured the intercondylar notch width. We believe that this level corresponds to high values of the anterior and posterior width of intercondylar notch.

The inner angle of the lateral condyle and femoral Q angle expressed in degrees (°), intercondylar notch width in millimeters (mm), height in centimeters (cm), weight in kilograms (kg) and BMI in kilograms per square meter (kg/m^2).

Statistics

Normality of distribution was tested by Kolmogorov-Smirnov test, and all continuous variables deviated significantly from normal distribution, which is used median and interquartile range as the mean value and dispersion measures, a Mann-Whitney U-test as a nonparametric test for testing differences. In creating a predictive model was used in binary logistic regression.

Results

Analysis of the data of the study (Table1) shows that the injured subjects had significantly higher inner angle

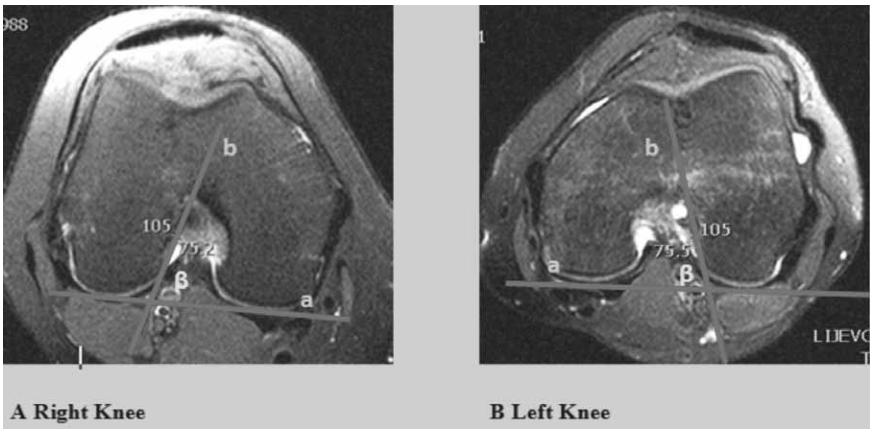

Fig. 1. A and B. Measurement inner angle lateral femoral condyle in axial plane.

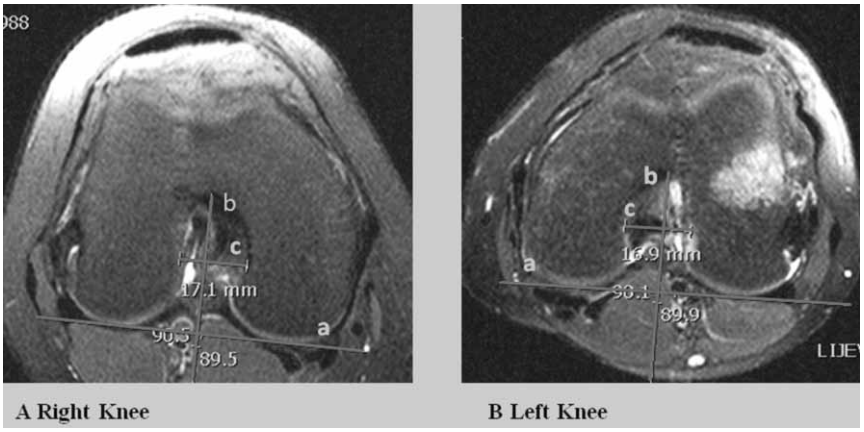

Fig. 2. A and B. Measurement intercondylar notch in axial plane.

TABLE 1

Variables	C [Q] Variables		Mann-Whitney U	p
	Healthy	Injured		
Age	17.00 [5]	21.00 [7]	211.500	0.031
Height	173.00 [7]	173.50 [11]	269.500	0.303
Weight	66.00 [7]	68.50 [7]	272.500	0.329
BMI	23.00 [3]	22.50 [3]	317.000	0.893
19 Q kut	15 [2]	16 [2]	284.500	0.420
Inner angle	68.00 [3]	75.00 [2]	<0.001	<0.001
Notch width	21.50 [1.40]	18.50 [2.05]	29.000	<0.001

of the lateral femoral condyle in the axial plane. For the injured respondent study this angle amounted to 75.00 [2], and for healthy participants 68.00 [3].

It also injured respondents of the study had statistically significantly narrower intercondylar notch width. For the injured respondents in median intercondylar width amounted to 18.50 [2.05], and for healthy control group amounted to 21.5 [1.40]. The median age in the study group was 17.00 [5], and the median age in the control group was 21.00 [7]. The average height is in the test group (injured) was 173.50 [11], a healthy control group 173.00 [7]. The median weight of the injured was 68.50 [7], a healthy 66.00 [7]. BMI in the test group was 23.00 [3], and in the control group 22.5 [3]. Q angle of the treatment groups amounted to 15 [2], and in the control group 16 [2].

The study treated a total of 51 knees (24 injured knees and 27 healthy knees) than that right was 21 and left 30 (Table 2).

Of the 24 cases with rupture ACL15 had a rupture in the level of the proximal third, 9 in the level of the middle third, while none was in the level of the distal third ACL (Table 3).

TABLE 2
KNEE SIDE

		Frequency	Percent
Valid	Right	21	41.2
	Left	30	58.8
	Total	51	100.0

TABLE 3
TEAR LEVEL ACL

	Frequency		Percent	Valid Percent	Cumulative Percent
Valid	Proximal third	15	62.5	62.5	62.5
	Middle third	9	37.5	37.5	100.0
	Total	24	100.0	100.0	

Discussion

Analyzing the results of our study we found that two variables have the statistics significance. Intercondylar notch width is from Palmer[11] in 1938 marked as a possible risk factor for ACL injury. It has been confirmed in numerous studies behind it, especially in the last two decades. And our study shows that all the injured handball players had narrower intercondylar notch width than in the control group. The median width of the intercondylar notch in injured was 18.5 [2.05] mm, whereas the healthy group had a median width of the intercondylar notch 21.5 [1.40] mm. Lund-Hansen and colleagues[16] have shown that athletes with a intercondylar notch width less than 17 mm had six times more likely to tear the ACL than the athletes with the width of notches greater than 17 mm, while the injured handball players from our test group had a slightly higher intercondylar notch width. It is good to note that the Lund-Hansen and colleagues measured the width of the notch on the radiographs done by Holmblad–in, and our measurements were on the axial MR sections in the level intercondylar notch and the need to look for this difference. The second statistically significant variable was the value of the internal angle of the lateral femoral condyle, which is the treatment groups amounted to 75.00 [2], and in the control group 68.00 [3], which had statistical significance of $p<0.001$. Stijak et al.[21] (22) found in the study group of women whose average age was 29.9±9.8 years, the value of the internal angle of the lateral femoral condyle the treatment groups amounted to 72.7°°±4.9, and in the control group 67.7°±6, 1°, which had statistical significance of $p<0.05$. The measured values in our study for the test group were on average 2.3° larger, while the value in the control group almost coincide, that was a slight increase of 0.3°.

Studied groups with ACL rupture has a greater angle of the inner side of the lateral fremoral condyle in the axial plane than respondents in the control group. In seven of the 25 injured handball intercondylar notch width is greater than the average width (18.5 mm) to 1 (one) or more mm, while in all the inner angle was injured in the median level of 75°. Were done using regression analysis shows that the beta coefficient of the inner angle ($\beta=0.725$, $t=8.346$, $p<0.001$) higher than the beta co-

efficient of the width of cracks (β=–0.233, t=–2.686, p< 0.001) and thus predicts ACL injury. Our study shows that there is no statistical significance of physical values that we measured (age, height, weight, BMI, Q angle) to the higher incidence of ACL injuries in the study group. There is also no significant differences in the ratio of right and left knees (χ^2 test=1.588, p=0.208). Although a significantly higher number of rupture was at the level of the proximal third ACL analysis by χ^2 test, there were no significant differences in the ratio of rupture (χ^2 test= 1.500, p=0.221).

Conclusion

Analysis and statistical evaluation of these parameters from our study indicates that:

Handball players from the test group (with Ruptured ACL) have a smaller intercondylar notch width than the control (healthy) group.

Handball players from the treatment groups (with Ruptured ACL) have a higher internal angle of the lateral femoral condyle in a axial plane relative to the control (healthy) group.

The inner angle of the lateral femoral condyle predicts ACL injury than the intercondylar notch width.

No statistical significance of physical values that we measured (age, height, weight, BMI, Q angle) to the higher incidence of ACL injuries in the study group.

Also no significant differences in the ratio of right and left knee and no significant differences in the extent of rupture between the test and control groups.

Therefore, we conclude that the smaller intercondylar notch width and larger inner angle of the lateral femoral condyle in a axial plane having an impact on a number of ACL rupture in handball female players in Herzegovina. We conclude that the larger inner angle better predicts ACL injury than the intercondylar notch width. How far the largest number of ACL rupture in our study were at the level of the proximal third refers to the importance of the inner side of the lateral femoral condyle, which contribute to impingement ACL ruptures. For injuries that operational planning ACL reconstructive surgery it is appropriate to consider if you have these risk factors on notchplasty.

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ŠIRINA INTERKONDILARNE UDUBINE I UNUTARNJI KUT LATERALNOG FEMORALNOG KONDILA U HORIZONTALNOJ RAVNI ČIMBENICI RIZIKA ZA OZLJEDE PREDNJE UKRIŽENE SVEZE KOD RUKOMETAŠICA U HERCEGOVINI

S A Ž E T A K

Cilj studije je ispitati širinu interkondilarne udubine i unutarnjeg kuta lateralnog femoralnog kondila kao čimbenike rizika za nekontaktnu ozljedu prednje ukrižne sveze (engl. Anterior Cruciate Ligament – ACL) kod rukometašica u Hercegovini. Dalje cilj je ispitati povezanost ovih čimbenika rizika za rupturu ACL sa fizičkim karakteristikama ispitanika, tj. tjelesnom težinom visinom i indeksom tjelesne mase (engl. Body Mass Index – BMI). Čimbenici koji utječu na nekontaktne ozljede ACL su različiti i dijele se na vanjske (vrstu sportske obuće, tip sportske podloge, vrijeme) i unutarnje čimbenike (anatomske, neuromuskularne, biomehaničke i hormonalne). Među anatomskim, uočeno je da su širina interkondilarne udubine, a u novijim studijama i kut lateralnog femoralnog kondila u horizontalnoj ravni označeni kao čimbenici, koji dovode do sraza ACL uz medijalni rub prednjeg dijela lateralnog femoralnog kondila, te bi mogli biti povezani s povećanim rizikom ozljede ACL. Ispitali smo 24 rukometašice koje su imale unilateralnu nekontaktnu ozljedu ACL. Kontrolna grupa je bila 27 zdravih rukometašica. Svakoj je urađen ortopedski pregled. Širina interkondilarne udubine i vrijednost unutarnjeg kuta lateralnog kondila femura mjereni su na transverzalnom MR snimku. Rukometašice iz ispitivane skupine imaju veći unutarnji kut lateralnog femoralnog kondila u horizontalnoj ravni u odnosu na kontrolnu skupinu i manju širinu interkondilarne udubine. Rezultati pokazuju da unutarnji kut lateralnog femoralnog kondila u horizontalnoj ravni bolje predviđa ozljedu ACL od širine interkondilarne udubine.